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9 January 2002

# RTCA Special Committee 186, Working Group 3

# ADS-B 1090 MOPS, Revision A

# Meeting #9

## Action Item 8-11

## Draft 2

## Revision to Appendix D to Include TIS-B Ground Processing


**Presented by Vincent Orlando**



**SUMMARY**

**This working paper presents a second draft of a revision to Appendix D to include TIS-B ground processing. The initial draft included a new introduction to cover both ATC surveillance and TIS-B. The current paragraphs of Appendix D have been renumbered to make provision for a section on TIS-B.**

**Based on agreement at Meeting 8, the TIS-B ground processing material in Appendix D will only address issues specifically related to 1090 MHz. The remainder of the ground processing requirements will be included in a reference to the TIS-B MASPS. All of paragraph D.3 has been revised to incorporate this approach.**

# APPENDIX D REV A

# 1090 MHz
# GROUND ARCHITECTURE EXAMPLES

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## D.1 Introduction and Purpose

This appendix defines examples of ground architectures that can support (1) surveillance for ATC using extended squitter ADS-B reports and (2) Traffic Information Service Broadcast (TIS-B) on 1090 MHz.

ATC Surveillance

Although the first operational uses of extended squitter are expected to be in air-to-air applications, the FAA is also interested in extended squitter as a means of surveillance of aircraft via ground stations. Surveillance of both airborne aircraft and aircraft on the airport surface are of interest. The FAA has been investigating ground architectures that would be appropriate for this purpose. The results are summarized in this appendix. An example 1090 ground architecture for high density airspace in a current radar environment is summarized in this appendix. As new information arises from programs such as Safe Flight 21 and Alaska Capstone, the FAA and the NAS users will collectively revise the architecture to refine the course of NAS modernization.

Note that the Traffic Information Service (TIS) capability is not included in the extended squitter ground station, since this service will be provided by conventional secondary radars with Mode S capability.

Traffic Information Service Broadcast

Traffic Information Service Broadcast (TIS-B) is a ground-to-aircraft broadcast service that provides "ADS-B like" surveillance transmissions for aircraft that are not equipped for ADS-B. TIS-B makes non-equipped aircraft visible to an aircraft with an ADS-B receiver. The surveillance source for this ground-to-aircraft broadcast can be a rotating beam terminal or enroute radar. Another possible surveillance source is an approach or surface multilateration system. Such multilateration systems provide a higher update rate and better surveillance accuracy than terminal or enroute radars.

TIS-B is considered to be an integral part of an ADS-B system since it is an important element in transition. If extended squitter surveillance is in use in a region of airspace, TIS-B can make all aircraft visible to a user with a 1090 MHz receiver even though not all aircraft are equipped for extended squitter.

## D.2 ATC Surveillance

### D.2.1 Avionics Equipage

In order to achieve a surveillance system that is based on extended squitter, it is necessary to define a transition strategy for integrating extended squitter into the existing system that will accommodate the mixed environment that will exist for many years during the transition from SSR to a possible full use of extended squitter. For this reason, the following avionics equipment must be accommodated:

1. Mode A/C transponder

2. Mode S transponder without extended squitter

3. Mode S transponder with extended squitter

4. Non-transponder extended squitter device.

### D.2.2 Transition Issues

A number of issues must be addressed in this transition strategy. Significant issues include:

1. Potential loss of independence between surveillance, navigation and communication functions.

2. Validation (or at least a reasonableness test) of reported position until reliability of this data is established by experience.

3. Surveillance in a mixed ADS-B/SSR environment for ATC airborne and surface surveillance

4. Backup surveillance for loss of GNSS function for individual aircraft due to an equipment malfunction.

5. Backup surveillance for loss of GNSS function over an extended area due to interference effects on GNSS operation.

6. The ability to suppress the creation of tracks on ADS-B reports that contain intentionally incorrect position information (i.e., spoofers).

### D.2.3 Ground surveillance of airborne aircraft

#### D.2.3.1 Surveillance techniques

##### D.2,3.1.1 Current technology

ATC surveillance of airborne aircraft is currently provided by narrow scanning beam SSR’s often collocated with primary radars. SSR’s intended for terminal surveillance have a maximum range of 60 to 100 NM and a scan interval of 4 to 6 seconds. En route coverage is provided by SSR’s with a maximum range of 200 to 250 NM and a scan interval of 8 to 12 seconds.

Different capabilities exist for these SSR’s. This includes Mode A/C only capability based on sliding window or monopulse azimuth processing. The newest SSR’s have Mode S (and Mode A/C) capability with monopulse azimuth determination. Mode S interrogators are able to support the readout of aircraft developed information on identity, aircraft state and intent. This latter capability is referred to as enhanced surveillance.

##### D.2.3.1.2 End state surveillance using extended squitter

The extended squitter technique provides formats for airborne use that are optimized for ATC surveillance. These formats include position, velocity, ICAO address and aircraft call sign. Provision is made to report the quality of the reported surveillance data based upon the accuracy of the navigation source data.

As appropriate experience is gained and a transition is made to ADS-B, squitter receiving stations might be able to replace some current SSR's. Terminal area squitter stations would have ranges up to 100 NM. Squitter stations would provide coverage up to 250 NM in en route airspace and up to 300 NM as required in remote areas. The squitter stations would be capable of transmitting interrogations in order to obtain additional information from the transponder, such as intent and Mode A code.

While these stations would provide omni-directional coverage, in most cases this would be achieved with an antenna having six to twelve sectors. Operation with such an antenna requires the use of a receiver associated with each antenna sector, with a single transmitter that may be switched between the sectors as required. The use of multiple sectors will be required at high density environments for increased traffic capacity, since each receiver only has to cope with the traffic in one sector. Such an antenna will also be required at en route stations in order to achieve the antenna gain required for long range operation. For illustrative purposes, six-sector antennas are used in this appendix for ground system configuration examples employing multi-sector antennas.

### D.2.3.2 Airspace considerations

The potential for transition of ATC surveillance to extended squitter depends on the type of airspace being covered. The most likely application of extended squitter will be in airspace that does not currently have secondary radar surveillance coverage. This could be in a remote area or low altitude coverage in any airspace.

It is unlikely that ADS-B will replace secondary radar surveillance in any high density airspace for the foreseeable future. A principal consideration is the need for independence between surveillance and navigation in such airspace. A second consideration is the vulnerability of satellite navigation sources to low level interference. Such an interference event could result in the loss of satellite navigation service over areas measured in tens of kilometers. Providing backup surveillance for large numbers of aircraft will significantly increase the cost of the ADS-B ground station to the point where ADS-B may not be an cost effective replacement for radar. ADS-B replacement of secondary radar in high density airspace will likely require the development of a robust satellite navigation source, or the use of an alternate navigation source such as an inertial platform as a backup.

### D.2.3.3 Transition strategy

#### D.2.3.3.1 Validation

If necessary, position validation can be performed by a single station equipped with a multi-sector antenna. Range would be determined by direct interrogation of the transponder, while bearing would be determined by measuring the relative amplitude of the received signals in the antenna sectors. Aircraft equipped with a non transponder device would only be able to support bearing validation unless the ground system is equipped with multi-lateration capability (e.g., airport surface surveillance).

Analysis indicates that a six-sector antenna can provide a bearing accuracy of around 2 degrees. This should be accurate enough for a reasonableness test in low density airspace, but would not be sufficient for a terminal area.

Where provided for backup service, multi-lateration can be performed in the background mode for validated aircraft for periodic revalidation of position. When validation is performed by direct interrogation, a technique similar to TCAS hybrid surveillance could be implemented to revalidate aircraft that have flight paths in close proximity to other aircraft.

#### D.2.3.3.2 Backup

If necessary, backup surveillance could be provided in terminal environments using a time- difference of arrival multi-lateration technique. Multi-lateration will require the use of multiple receiving stations. This could be configured as a central station surrounded by three or more outrigger stations. In this configuration, the central station would be a full extended squitter ground station with transmit and receive capability and a multi-sector antenna. The outrigger stations would be simple receivers with omni-directional antennas. If the multi-lateration system is provided with sufficient capacity, multi-lateration could provide backup for single aircraft or area failures of GNSS functionality.

Where multi-lateration is not available, aircraft will need to be interrogated at the nominal scan interval. Backup surveillance for non-transponder devices would only be possible if multiple bearing measurements are available through overlapping ground station coverage.

#### D.2.3.3.3 Mixed equipage

Surveillance on Mode S aircraft that are not equipped with extended squitter can be performed using multi-lateration on the short squitter, or by direct interrogation.

Surveillance of Mode A/C only aircraft would require an active interrogation approach. The use of active interrogations (single or whisper shout depending upon the Mode A/C traffic density) would be used to elicit Mode A or C replies at a regular rate. In effect, the ground station operates like a TCAS unit, but with a lower interrogation rate and at higher effective radiated power due to its increased operating range. Since the majority of the aircraft in high density environments will be Mode S equipped, at most 8 whisper/shout levels should be needed for Mode A/C surveillance out to 60 to 100 NM. The central station could obtain range and a coarse bearing estimate from its multi-sector antenna. The position could be refined by use of multi-lateration data from the outriggers. The coarse position estimate would be very helpful in eliminating phantoms (position reports made up of replies from different aircraft). Sidelobe suppression will be required to limit replies in the antenna sidelobes.

### D.2.3.4 Special considerations for precision runway monitoring

One surveillance application is the monitoring of aircraft on precision approaches. This is sometimes referred to as precision runway monitoring (PRM). Using current technology, aircraft navigate on the approach using ILS or MLS and are monitored by

SSR, sometimes operating at a higher scan rate than for normal ATC surveillance. Thus the navigation and monitoring techniques are completely independent.

Consideration is being given to use GNSS as the basis for future landing systems. If GNSS is used for this purpose, it is likely that some independent form of validation would be required for ADS-B surveillance data before it could also be used for PRM. Without independent validation, ADS-B for PRM would not be able to detect a blunder caused by a malfunction of the navigation equipment. Such a malfunction would result in both the air crew and the ground believing that the aircraft was on the correct approach, when in fact a deviation had occurred.

One example of a validation for PRM is the use of multi-lateration on the extended squitter transmission, as described earlier. This technique would provide the necessary independence of surveillance and navigation. Another example of independent validation of the ADS-B reports from aircraft is readout of the ADS-B message and comparison to the ground radar position when the airport is equipped with a Mode S interrogator.

Another application of ADS-B in PRM is to use CDTI and associated alert algorithms for monitoring parallel approaches. To support this air-to-air application of ADS-B, current ground-based technique should be adequate as monitoring responsibility rests primarily in the cockpit.

### D.2.4 Surface surveillance

#### D.2.4.1 Surveillance techniques

##### D.2.4.1.1 Current technology

Current surveillance on the airport surface is provided by primary radar in the form of the Airport Surface Detection Equipment (ASDE). The ASDE provides reliable surveillance on all targets (regardless of equipage) but does not provide identity which is useful for blunder detection and resolution. For this reason, techniques for providing aircraft identity using the aircraft transponder are being considered.

Surveillance on the airport surface requires that the positional error be small compared to the size of an aircraft in order to provide reliable correlation with the ASDE report. This rules out the use of direct range and azimuth measurement, or even range-range multi-lateration due to the tolerance in the transponder turnaround delay. For this reason, SSR-based surface systems under development use time-difference of arrival multi-lateration, since it is based only on the difference in time of the receipt of an aircraft transmission at spatially diverse ground stations.

##### D.2.4.1.2 End state surveillance using extended squitter

The extended squitter design provides formats for use on the airport surface that are optimized for surface surveillance. These formats include position, velocity, ICAO address and aircraft call sign. The accuracy needed for surface surveillance can be supported by GNSS using local or wide area differential corrections.

### D.2.4.2 Transition strategy

#### D.2.4.2.1 Validation

If necessary, validation of surface position reports can be performed using multi-lateration on the extended squitter transmission. Once validated, the ADS-B reports can be used for improved surveillance performance. Multi-lateration can be performed in the background mode for validated aircraft for periodic revalidation of position.

#### D.2.4.2.2 Backup

The background process of multi-lateration provides position and identity for short or long squitter reports that do not contain GNSS position information. A total loss of GNSS service would cause the surveillance system to revert to full multi-lateration operation. This would result in lower surveillance performance since the position accuracy and update rate will be somewhat degraded and the aircraft will no longer provide velocity information. However, surveillance could continue throughout the loss of GNSS service.

#### D.2.4.2.3 Mixed equipage

With multi-lateration, the only aircraft requirement for surveillance is a periodic transmission. All Mode S transponders (even those that do not support extended squitter) transmit a short squitter on an average of once per second. This is a high enough rate to support multi-lateration for surface surveillance.

Mode A/C transponders do not squitter, so provision would have to be made to elicit periodic replies if Mode A/C aircraft are to participate in surface surveillance during the transition period. One approach is to modify the transponders to generate a reply once per second. This may not be a feasible approach, since high equipment modification costs could lead operators to resist such a modification. A second approach may be used if only a small percentage of surface aircraft are Mode A/C equipped (i.e., most aircraft are Mode S equipped). This approach is based on the use of the whisper/shout technique used by TCAS to interrogate only a subset of the Mode A/C aircraft within range. Initial field measurements indicate that this technique may be able to support as many as 15 to 20 Mode A/C surface aircraft.

### D.2.5 Transition strategy summary

A strategy for transitioning from an SSR to an extended squitter environment has been defined. The strategy makes use of the capabilities of those SSR transponders to support validation, backup and mixed equipage scenarios through direct range and bearing measurement and multilateration. Since the ADS-B message is contained in an SSR waveform, the same equipment that is needed for independent position measurement of the SSR transponders can also be used to receive the ADS-B squitters. Transition is greatly simplified by the integration of the ADS-B function with the Mode S transponder.

## D.2.6 Ground Architecture for Air-Ground surveillance

### D.2.6.1 Introduction

#### D.2.6.1.1 Purpose

The previous sections described a possible transition strategy for ATC use of extended squitter. The capability of extended squitter ground receiving stations was defined in general operational terms. The purpose of this section is to provide more details on the architecture that might be used to provide extended squitter surveillance for ground ATC use.

#### D.2.6.1.2 Overview

This section begins with a description of the currently implemented Mode S ground interrogators. This is relevant to extended squitter since ADS-B surveillance data can be obtained by a conventional Mode S interrogator via direct readout of the Mode S transponder. Such readout will likely be the initial technique for ATC use of ADS-B data. This is followed by a description of the architecture of increasingly more capable extended squitter ground stations.

#### D.2.6.1.3 Interface Considerations

Extended squitter ground stations will require the ability to interface with other ATC surveillance resources to generate a consolidated surveillance image. For this reason, these ground stations will be required to conform to an appropriate output interface standard (e.g., the internationally accepted Eurocontrol ASTERIX formats).

### D.2.6.2 Mode S SSR Ground Station

A Mode S SSR normally operates with a scanning narrow beam antenna. This antenna is often mounted on the same pedestal as a collocated primary radar. Terminal Mode S SSRs operate with a scan time of 4 to 6 seconds and provide coverage out to 60 to 100 NM. En route Mode S SSRs operate with scan times of 8 to 12 seconds out to a range of 200 to 250 NM. A functional diagram of a Mode S SSR ground station is provided in Figure D 2-1.

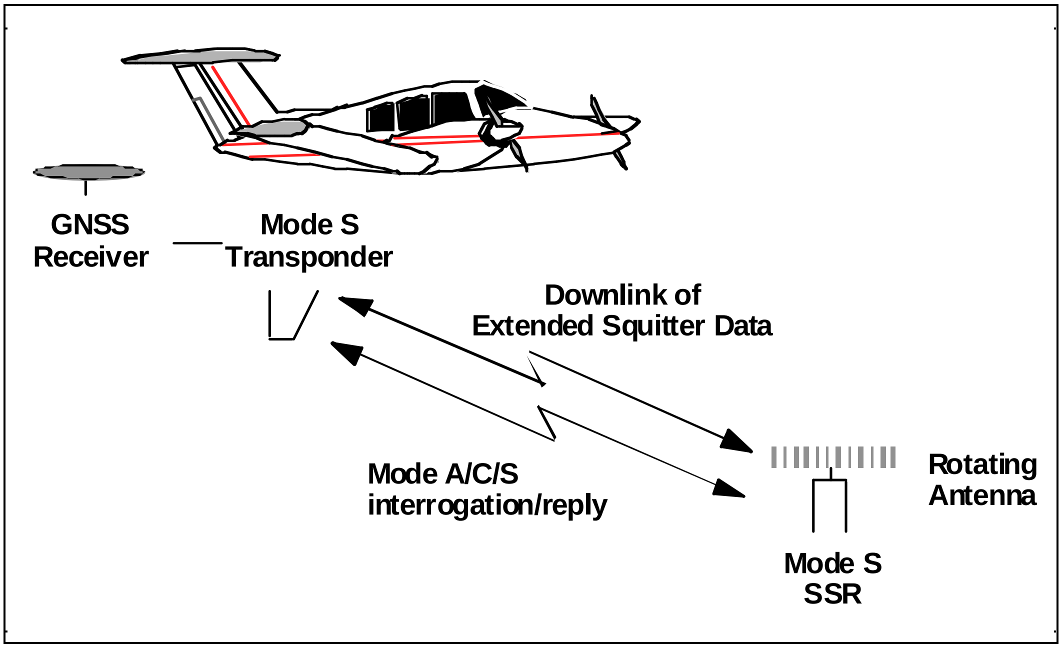


**Figure D 2-1 Mode S Secondary Surveillance Radar ground station providing surveillance of all Mode A/C/S aircraft in high density environments, as well as ADS-B surveillance (via enhanced surveillance), validation and spoofing resistance.**

A Mode S SSR provides surveillance and data link service to Mode S equipped aircraft and surveillance service for Mode A/C equipped aircraft. Due to the use of monopulse (a technique for determining the off-boresight angle of received replies) surveillance to a Mode S aircraft is normally provided via a single interrogation per scan. Additional interrogations are scheduled each scan as needed to provide data link service.

One data link service supported by a Mode S SSR is the readout of transponder data registers that can be loaded by the aircraft to contain aircraft state, intent, weather data, etc. These registers can be accessed on demand by the Mode S SSR using the ground initiated Comm-B (GICB) protocol. This protocol is employed to provide the enhanced surveillance capability being mandated by States in the core area of central Europe.

Extended squitter information that is broadcast by a Mode S transponder is stored in the GICB registers. This means that ADS-B data is available on demand to a Mode S SSR. The ability to obtain GNSS position and velocity, as well as intent information, via a Mode S SSR can be an important benefit during a transition to ADS-B. In addition, ground readout of ADS-B data provides an opportunity to monitor the status of ADS-B implementation and, more importantly, the reliability of this data since it can be directly compared to the Mode S radar data.

### D.2.6.3 Extended Squitter Ground Stations

#### D.2.6.3.1 Overview

An extended squitter ground station can be configured to provide different levels of performance as required.

A block diagram of the subsystems that could be included in a basic extended squitter transmit/receive ground stations is shown in Figure D 2-2. The configuration shown is for a ground station with an omni-directional antenna. A ground system with a multi-sector antenna would require a receiver and reply processors for each antenna sector. A single transmitter would be used, with a switch to connect it to any antenna sector under control of the computer system.

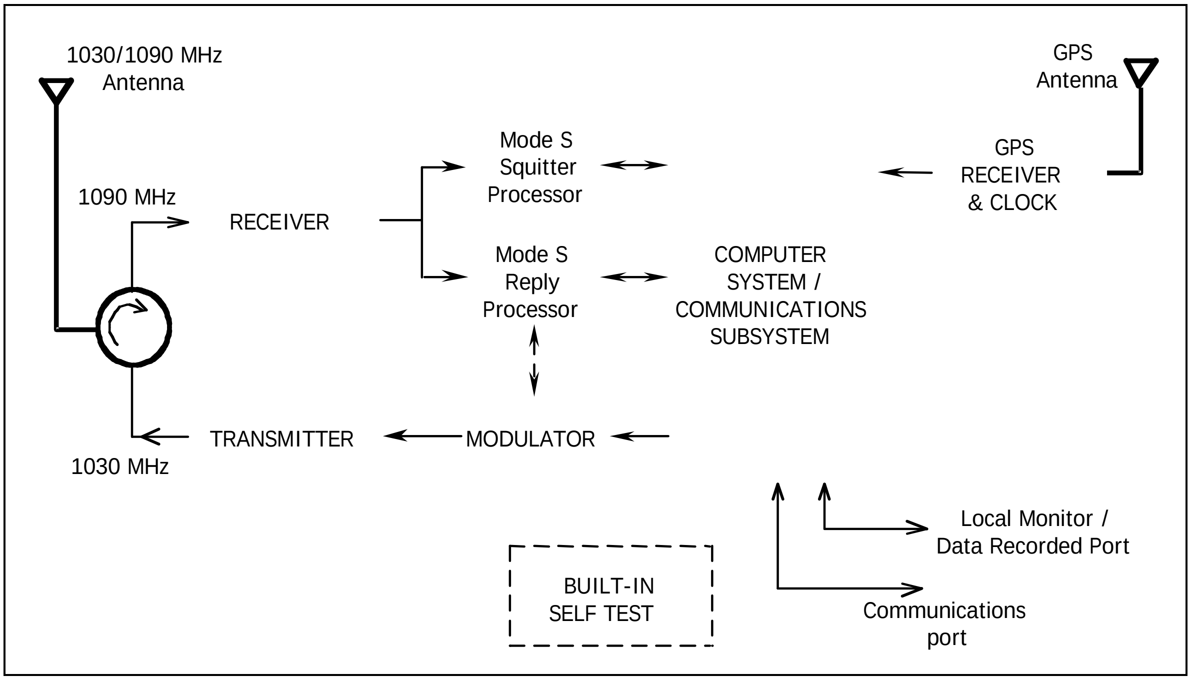


**Figure D 2-2 Basic Extended Squitter System Block Diagram.**

**D.2.6.3.2. Omni Antenna, Receive only**

Capabilities: The simplest ground station only has the ability to passively receive extended squitter ADS-B reports. It operates with an omni directional antenna.

Intended Use: This configuration is expected to be used in low density or remote airspace not currently within ATC surveillance coverage.

A block diagram of this configuration is presented in Figure D 2-3.

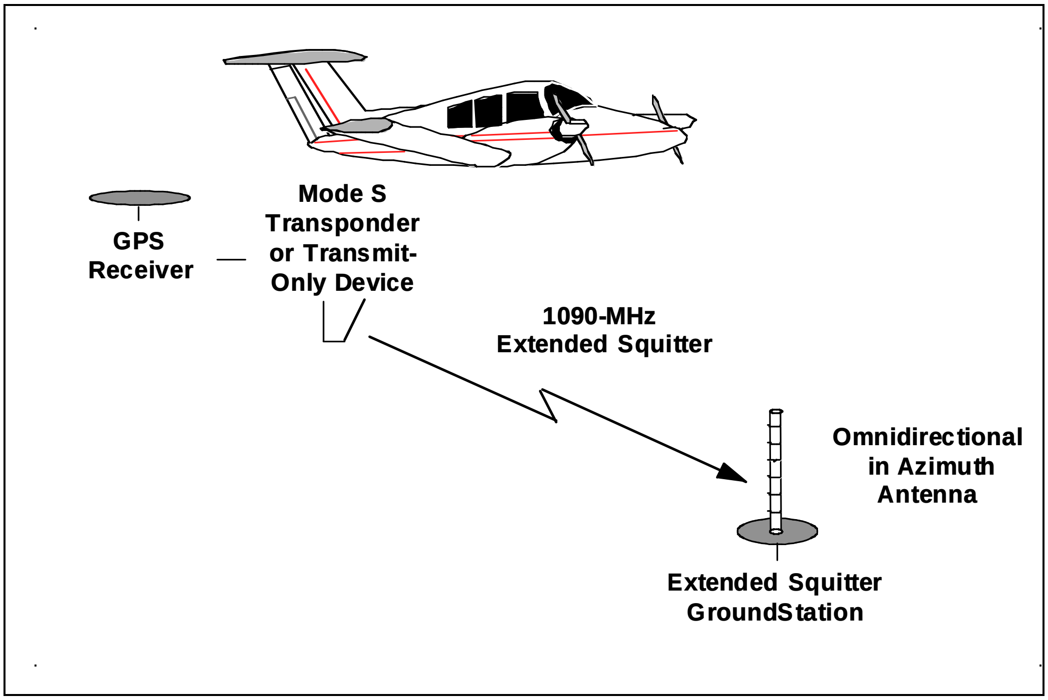


**Figure D 2-3 Simple receive-only extended squitter ground station configuration providing ADS-B surveillance.**

**D.2.6.3.3. Omni Antenna, Receive only, Angle of Arrival Capability**

Capabilities: This configuration provides the same reception capability as above, but it is augmented with a simple angle-of-arrival capability in order to obtain an approximate estimate of aircraft azimuth. This ground station configuration can provide azimuth validation on ADS-B equipped aircraft in low density airspace. Azimuth accuracy for such an antenna has been measured to be approximately 8 degrees, one sigma.

Validation: The angle-of-arrival validation capability enables the ground station to provide approximate validation of the ADS-B azimuth through direct comparison of the actively measured azimuth with the azimuth calculated from the ADS-B position report. In cases where overlapping coverage exists for this type of ground station, approximate aircraft positions can be developed using azimuth triangulation from the ground stations. This system allows for independent validation of ADS-B position reports.

Intended Use: The approximate position location provided by this configuration would make it suitable only for use in low density airspace.

A block diagram of this configuration is presented in Figure D 2-4. Note that multiple stations of this type that have overlapping coverage could perform azimuth triangulation.

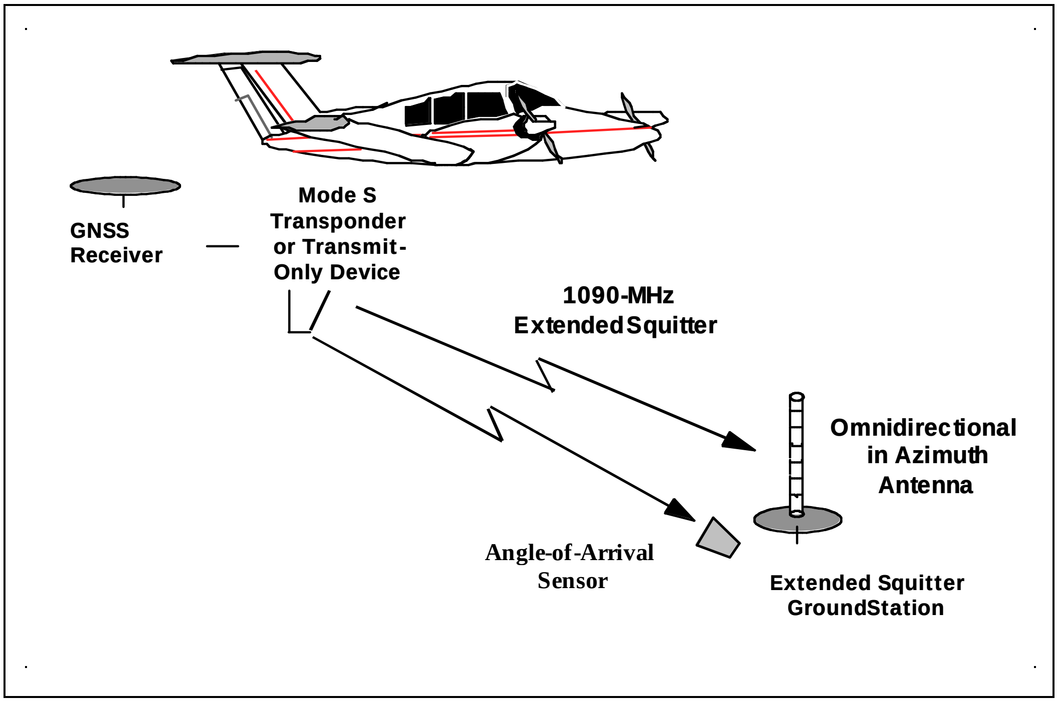


**Figure D 2-4 Receive only extended squitter ground station with angle-of-arrival sensor configuration providing ADS-B surveillance, azimuth verification and spoofing resistance.**

### D.2.6.3.4. Six-Sector Antenna, Receive/Transmit

Capabilities: This configuration provides the same reception capabilities as the preceding configuration. In addition, it is equipped with a six-sector antenna, with one receiver per antenna beam and a single transmitter that may be switched to any beam as required. The use of the six-sector antenna allows operation into higher density than is possible with an omni antenna, since each receiver has to cope only with the squitters and Mode A/C replies received from a single antenna beam. An analysis of sidelobe structure and traffic distribution indicates that such an antenna can be expected to provide a capacity 2.5 times the capacity of a ground station using an omni-directional antenna.

Validation and Fall-Back Surveillance: In addition to increased capacity, the six-sector antenna enables this ground station to provide a higher level of validation than the omni directional configuration. This is due to the ability of the six-sector antenna to provide azimuth measurement to an accuracy of 2-3 degrees using a simple amplitude monopulse processor. This coarse azimuth capability together with measured range (for a transponder implementation of extended squitter) can also be used to provide fall-back surveillance in the event of the loss of the navigation input for ADS-B. Fall-back surveillance refers to a lower performance form of surveillance that can be used during an outage of the principal surveillance system.

Mode S and Mode A/C Surveillance: The six-sector antenna enables this ground station configuration to provide improved surveillance on Mode S and Mode A/C equipped aircraft compared to the previous configuration.

Intended Use: This configuration is expected to be used in low to medium density en route airspace where a fall-back azimuth accuracy of 2-3 degrees may be operationally acceptable. Antennas with a greater number of sectors may be used to achieve higher capacity or improved azimuth measurement accuracy as required.

A block diagram of this configuration is presented in Figure D 2-5.

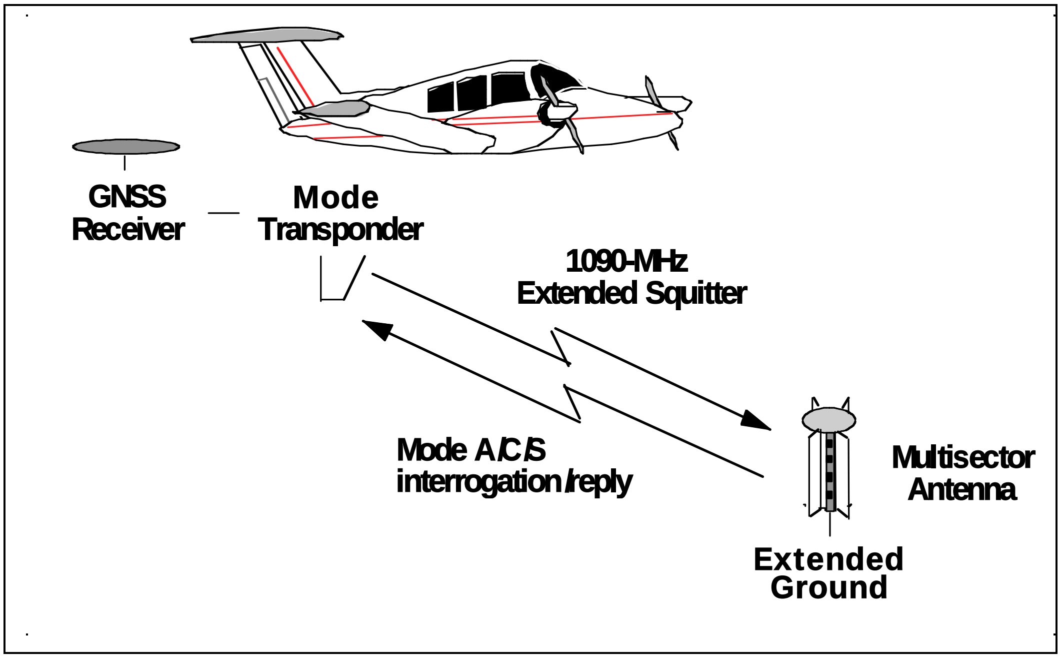


**Figure D 2-5 Extended squitter ground station providing ADS-B surveillance, position validation, spoofing resistance, coarse surveillance of all Mode A/C/S aircraft and fall-back surveillance for ADS-B aircraft.**

### D.2.6.3.5 Six-Sector Antenna, Receive/Transmit with Multilateration Augmentation

Capabilities: This configuration has all of the capabilities of the preceding ground stations, and in addition, is equipped with a number of additional receiving sites for the purpose of providing a time-difference of arrival multilateration capability. The additional stations needed for multilateration can be very simple, consisting of a 1090 MHz receiver, a reply processor, a GPS receiver (for accurate time tagging) and a telephone modem. The physical size would be small, about the size of an SSR transponder. However, intersite communications would be required and 3 or more sites would have to be in view of a particular aircraft in order to obtain a multilateration solution.

Backup Surveillance: Depending on the geometry of the ground stations, multilateration position accuracy can equal or exceed that of an SSR. With this level of position accuracy, backup surveillance is possible. Backup surveillance refers to an alternative surveillance capability that can be used during an outage of the principal surveillance system that provides equivalent performance to the principle system.

Mode S and Mode A/C Surveillance: As for the previous configuration, Mode S and Mode A/C surveillance capability can also be provided via active interrogation. The coarse position information provided by the six-sector antenna would be very useful in eliminating false targets that could otherwise result from performing multi-lateration on non-discrete Mode A Code replies.

Intended Use: The level of capability provided by this configuration would be appropriate for use in a terminal area.

A block diagram of this configuration is presented in Figure D 2-6.

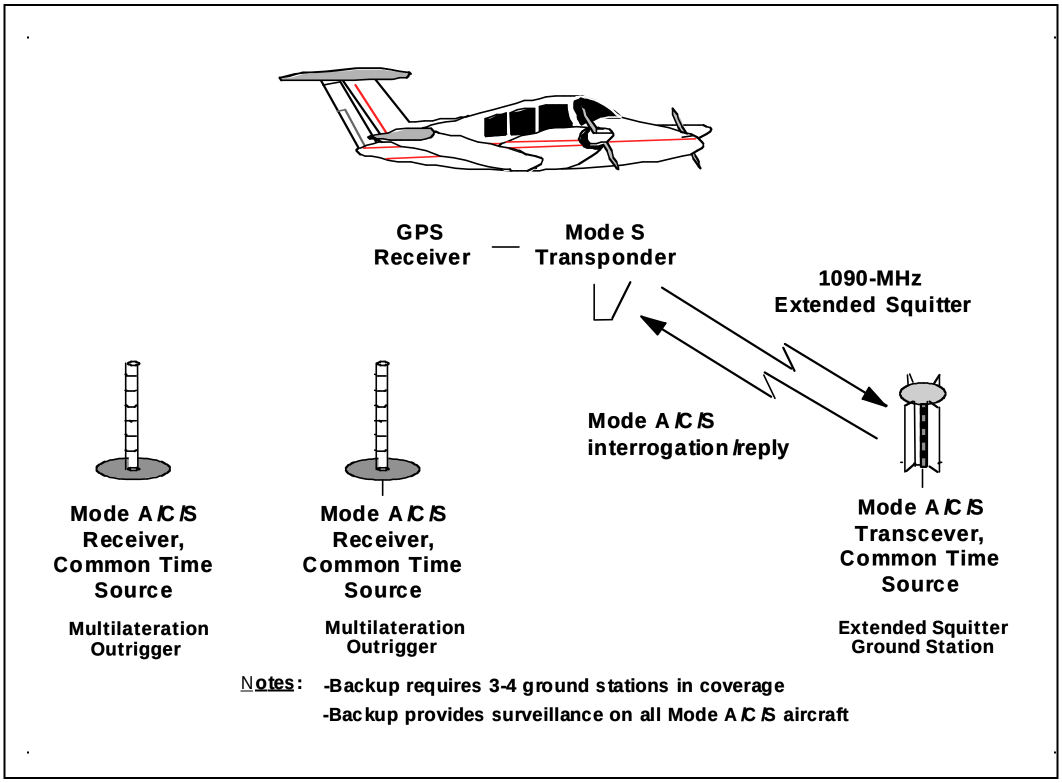


**Figure D 2-6 Extended squitter ground station providing ADS-B surveillance, position validation, spoofing resistance, accurate surveillance of all Mode A/C/S aircraft and backup surveillance for ADS-B aircraft.**

## D.2.7 Ground Architecture for Surface Surveillance

### D.2.7.1 Overview

The purpose of this section is to describe the ground architecture that may be used for surface surveillance using extended squitter. As indicated above, transition and validation requirements will require the use of multilateration is support of surface surveillance. In addition, inputs from air-ground surveillance devices will also be required to monitor arriving aircraft

### D.2.7.2 Extended Squitter Surface Ground System

Extended squitter ground stations for surface surveillance can be 1090 receive only or may have 1030 transmit capability in order to (optionally) manage surface squitter rates. These stations would use omni or single sector beam antennas as appropriate to cover the airport maneuvering area. Typically four to six such ground stations would be required.

### D.2.7.3 Candidate Ground Architecture

A candidate ground architecture for surface surveillance is shown in Figure D 2-7. This architecture features a surveillance server with data fusion capability to provide a surveillance picture based on the combined resources of ADS-B, multi-lateration, ASDE and the airport surveillance radar (ASR). This surveillance information is used to support a conflict alert algorithm. The surveillance and conflict alert results are provide to ground ATC. Provision is also made to data link alerts to the cockpit.

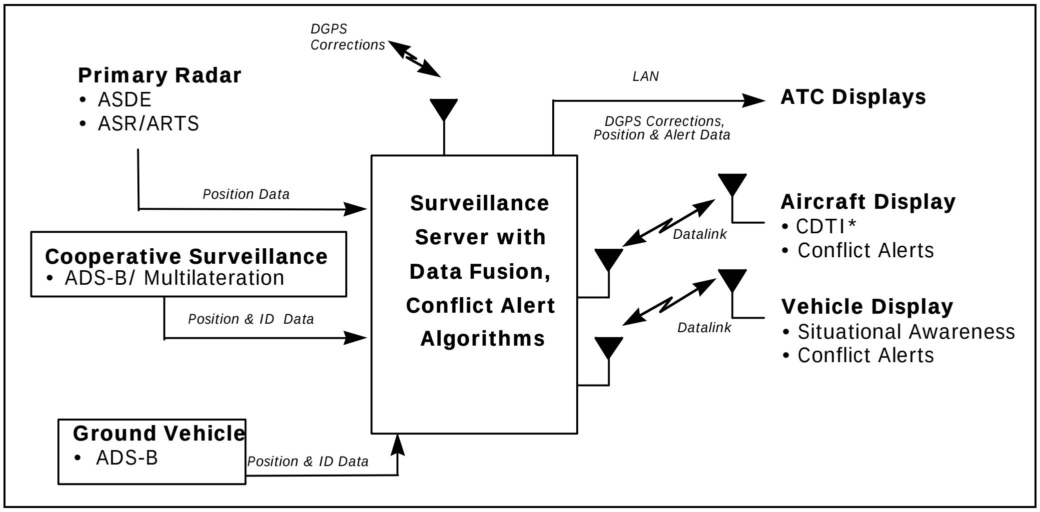


**Figure D 2-7 Ground architecture for surface surveillance using ADS-B, multilateration and radar.**

## D.2.8 Integration with Other Radars and Automation Systems

### D.2.8.1 Overview

With the introduction of ADS-B, the surveillance architecture will consist of a mix of primary and secondary radars, one or more of the ADS-B ground station options described earlier in this appendix and surface surveillance sensors including multi-lateration and ASDE. The sensors represent a mix in several respects:

- several different primary and secondary models,
- airport and en route equipage each support several different combinations of the primary and secondary models,
- surveillance installations interface with several different automation systems.

A few areas of CONUS, as well as parts of Alaska and Hawaii, currently have coverage gaps that may be filled with ADS-B ground stations, most likely with some degree of overlap. Most other areas currently have primary and secondary radars that provide substantial multiple coverage overlaps. The implementation of ADS-B ground stations in these areas will increase the basic coverage as well as the number of overlaps. Aircraft transponder equipage currently varies and it may well vary in the future with the ADS-B equipage options being considered.

*Given this substantial mix and the growth toward free flight, made possible with ADS-B, there is an underlying need for a flexible integration scheme which can exploit the improved surveillance track data base to produce unified tracks. That is, the sum of the track data available on a target from multiple surveillance sensors (radars and ADS-B) and from neighboring installations can be fused to provide a unified track on each target with much higher accuracy for ATC and ATM purposes. The FAA has been investigating methods that can fuse data from multiple and varied sensors toward this end goal.*

### D.2.8.2 The Need for Fusion

The need for sensor data fusion is predicated on several related key factors. They include:

- the surveillance sensor mixes encountered in the US and Internationally, particularly in European airspace,
- the absolute imperative to maintain safety as aircraft with mixed equipage share the same airspace will not allow reduced safe spacing requirements with current automation mosaicing techniques,
- the potential to reduce cost by reducing numbers of surveillance sensors may be enabled by fusing tracks from the remaining overlapping sensors,
- fused ground based surveillance from all sensor types data supports a seamless gate-to-gate view of aircraft (and surface vehicle) surveillance which will support future automation and procedural alternatives,
- fused data will provide a source of information to support an ADS-B related product known Traffic Information Service – Broadcast (TIS-B),
- supporting ATC and ATM in a Free Flight Environment requires improved surveillance performance in both air-air and air-ground modes, and
- efficiency in operations made possible by improved surveillance performance may lead to reduced separation minimums and reduced controller workload

### D.2.8.3 Architecture Considerations

Surveillance and Automation teams within the FAA are currently investigating several technical issues that must be considered in selecting an effective and affordable fusion architecture approach. Consideration must also be given to hardware and software implementations that can be introduced as part of a larger transition in the NAS modernization process. Conceptually, each automation end point will be supported by one or more surveillance servers and a surveillance hub. Together they will provide the necessary interface to process and integrate data, which can be synchronous, asynchronous and displaced in time due to sensor locations. Data formats will have to be upgraded to incorporate longer data messages per target, preserve sensor data accuracy and event time and introduce new message content such as pilot intent. Key technical considerations include:

- the number and type of sensors and automation systems which are to be served,
- the interface data format (ASTERIX is the primary candidate),
- the flexibility for compensating sensor bias (registration) errors since these are usually the limiting factor in fusion,
- the selection of data combining techniques , that is the combining of data reports before fused track files are formed versus the fusing of individual sensor track files versus a hybrid combination of both methods,
- adaptivity to sensor failures,
- communication requirements in terms of data link bandwidth,
- processor sizing and placement,
- current and projected state-of-the-art in fusion,
- the establishment of requirements to be applied to the surveillance data fusion system.

Figure D 2-8 illustrates an example of the many sites and types of equipage that would introduce target data to a surveillance hub and surveillance servers that implement fusion and provide a unified target data base to automation.

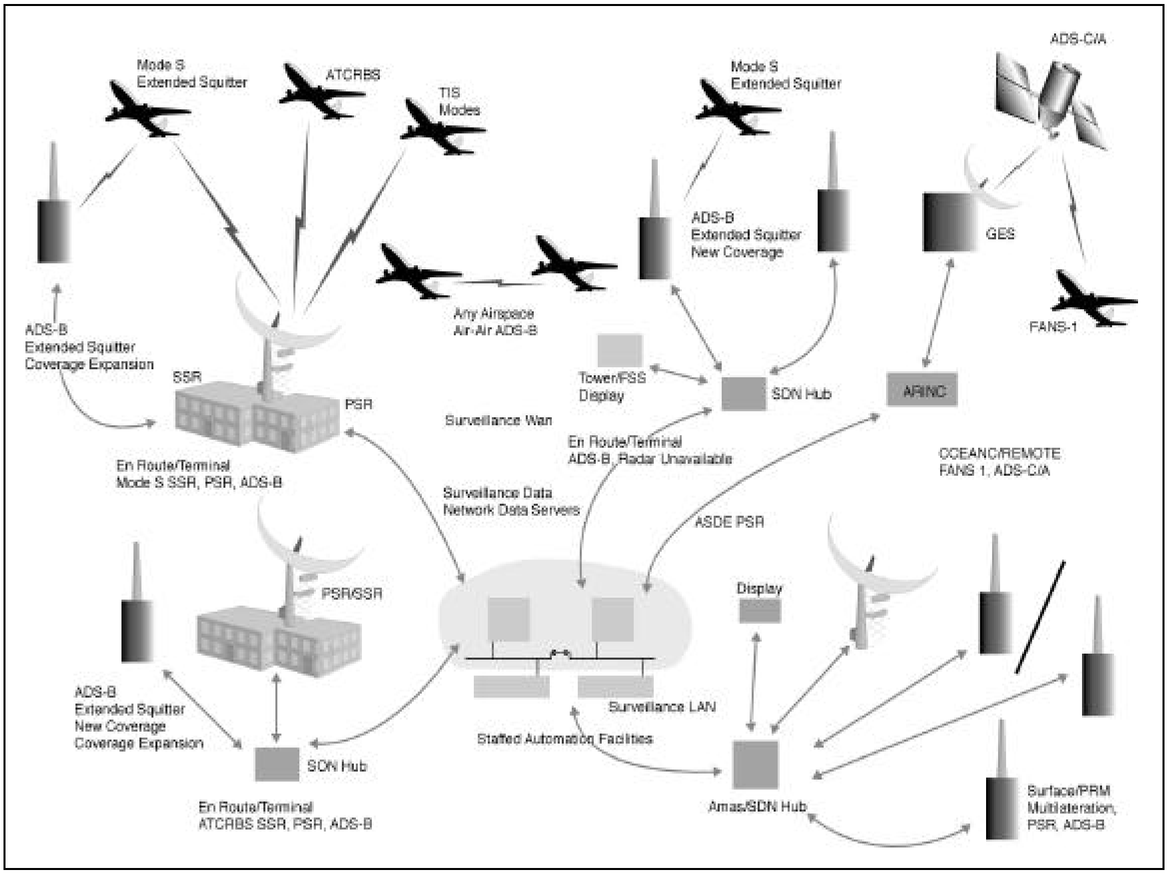


**Figure D 2-8 Conceptual architecture for implementing surveillance fusion of multi-sensor / multi-site target reports**

## D.2.9 ATC Surveillance Summary

The extended squitter system provides a wide range of options for aircraft surveillance.

For surveillance of airborne aircraft, these options range from simple, low cost, ADS-B receive-only ground stations, to a six-sector configuration with multi-lateration that can provide ADS-B service plus surveillance of Mode A/C/S aircraft suitable for use in a terminal area. In the highest density airspace, the option exists for the use of Mode S Secondary Surveillance Radars that will support the surveillance of all transponder equipped aircraft in addition to readout of ADS-B data.

For surface surveillance, these options include ADS-B only, or ADS-B in combination with multi-lateration to support transition and validation activities.

# D.3 Traffic Information Service Broadcast (TIS-B)

## D.3.1 Overview

The formats and protocols required for avionics implementing TIS-B on 1090 MHZ are specified the body of this MOPS and in Appendix A. Ground processing for TIS-B on 1090 MHz must implement these dame formats and compatible algorithms to interoperate with airborne equipment.

Specific requirements for the ground processing component of TIS-B are contained in the ADS-B MASPS (DO-TBD). The ADS-B MASPS contain requirements for TIS-B in a link independent manner. The purpose of this section of Appendix D is to provide additional guidance on implementing ground processing for TIS-B service on 1090 MHz.

### D.3.2 Ground Determination of Extended Squitter Equipage

The normal mode of TIS-B operation on 1090 MHz. is to provide this service only for aircraft that are not equipped with extended squitter. It is therefore necessary for TIS-B ground processing to determine which aircraft are extended squitter equipped.

Mode S transponders are equipped to provide a data link capability report in response to an interrogation from a Mode S ground radar. This data link report contains a bit flag to indicate if the transponder is equipped for extended squitter. However, this bit flag is not a reliable indicator of actual extended squitter operation. The bit flag is a static indication of the capability of the transponder support for extended squitter formats and protocols. It would not reflect the loss of extended quitter operation due to a malfunction of the transponder or to the navigation input.

The recommended technique for determining active extended squitter operation is to monitor 1090 MHz for extended squitter reception using in an omnidirectional fashion. The most convenient way to implement this monitoring is to equip the 1090 MHz TIS-B ground stations to receive as well as transmit. This approach will also provide extended squitter determination for aircraft equipped with non-transponder devices.

### D.3.3 TIS-B Antenna Siting to Enhance Equipage Determination

The most reliable configuration for the determination of active extended squitter operation is achieved if a ground radar (providing the basis for TIS-B service) and the TIS-B receiver-transmitter station cover the same volume of airspace. This avoids the situation where an extended squitter equipped aircraft is visible to the ground radar but not to the TIS-B station. In this case, the aircraft would not be declared to be extended squitter equipped and this would result in unnecessary TIS-B transmissions.

The way to achieve the same coverage for the ground radar and the TIS-B station is to locate the TIS-B antenna near and at about the same elevation as the ground radar antenna.

### D.3.4 Ground Radar Data Considerations

Wherever possible, the ground radar data used as the basis for TIS-B service should be based upon Mode S surveillance. The availability of ground surveillance data identified with the aircraft 24-bit address for Mode S equipped aircraft significantly enhances the correlation of ground surveillance data with received extended squitters. If an ATCRBS radar is used as the basis for TIS-B service, correlation between the ground radar data and the received extended squitters must be based only on position and altitude since Mode A code is not provided by any of the ADS-B systems

### D.3.9 TIS-B Summary

***TBD***